Arnold Schwarzenegger
Governor

REVIEW OF INTERNATIONAL EXPERIENCE INTEGRATING VARIABLE RENEWABLE ENERGY GENERATION

APPENDIX B: GERMANY

PIER PROJECT REPORT

Prepared For:

California Energy Commission
Public Interest Energy Research Program

Prepared By:

EXETER
ASSOCIATES, INC

April 2007
CEC-500-2007-029-APB

Prepared By:
Exeter Associates, Inc.
Kevin Porter
Columbia, Maryland
Commission Contract No. 500-02-004
Commission Work Authorization No: MR-017

Prepared For:
Public Interest Energy Research (PIER) Program
California Energy Commission

Michael Kane, Dora Yen-Nakafuji, Ph.D.
Contract Manager

Dora Yen-Nakafuji, Ph.D.
Project Manager

Elaine Sison-Lebrilla, P.E.
Manager
Energy Generation Research Office

Martha Krebs, Ph.D.
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION

B.B. Blevins
Executive Director

Acknowledgments

The California Energy Commission's Public Interest Energy Research program funded the work described in the report. The authors thank Dora Yen-Nakafuji and the California Wind Energy Collaborative team for their technical support. The authors also thank Thomas Ackerman of the Royal Institute of Technology in Sweden; Brendan Kirby of Oak Ridge National Laboratory; Brian Parsons and Michael Milligan of the National Renewable Energy Laboratory; Jim Blatchford and David Hawkins of the California Independent System Operator; J. Charles Smith of the Utility Wind Integration Group; Hannele Holttinen of the VTT Technical Research Center in Finland; Bernhard Ernst of the Rheinisch-Westfälisches Elektrizitätswerk Aktiengesellschaft (RWE) Transmission System Operator in Germany; Alberto Cena of Asociación Empresarial Eólica (AEE) in Spain; Lucy Craig of Garrad Hassan in Spain; Dave Olsen of West Wind Wires; Mark Ahlstrom of WindLogics Inc.; Tom Miller of Pacific Gas and Electric; Abraham Ellis of Public Service Company of New Mexico; and John Kehler of the Alberta Electric System Operator for answering numerous questions and providing useful insights. Any remaining errors or omissions are our own.

Please cite this report as follows:

Kevin Porter, Christina Mudd and Michelle Weisburger. 2007. *Review of International Experience Integrating Variable Renewable Energy Generation, Appendix B: Germany.* California Energy Commission, PIER Renewable Energy Technologies Program. CEC-500-2007-029-APB.

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission) conducts public interest research, development, and demonstration (RD&D) projects to benefit the electricity and natural gas ratepayers in California.

The PIER program strives to conduct the most promising public interest energy research by partnering with RD&D organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural /Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Review of International Experience Integrating Variable Renewable Energy Generation, Appendix B: Germany is the final report for a subtask of Task 3 for the PIER Intermittency Analysis Project (IAP), contract number 500-02-004, work authorization number MR-017, conducted by the IAP team comprised of the California Wind Energy Collaborative, Exeter Associates, BEW Engineering, Davis Power Consulting, and GE Energy Consulting (with assistance from AWS Truewind, National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Rumla Consulting). The information from this project contributes to PIER's Renewable Energy Technologies program.

For more information on the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at (916) 654-5164.

Table of Contents

List of Tables

List of Figures

Abstract

This report summarizes the experience in Germany through 2006 with integrating variable renewable energy generation, primarily wind generation, and discusses potential operating and mitigation strategies for incorporating variable renewable energy generation. Initially, wind development in consisted of smaller but numerous wind projects interconnected to the distribution grid, in contrast with larger, utility-scale wind projects interconnected to the transmission grid in the United States. The differences between Europe and the United States are starting to narrow as development of variable renewable energy generation (e.g. wind and solar) increases and as wind development takes place in more countries. In addition, as more utility-scale wind projects emerge, more countries are relying on common strategies, such as grid codes, to help integrate variable renewable energy generation. This report is a part of the Intermittency Analysis Project (IAP), a comprehensive project aimed at assessing the impact of increasing penetration of variable renewable energy generation in California. A review of the international experience will provide perspective and insight to the IAP analysis team on various techniques for managing intermittency.

Keywords: grid code, transmission system operators, turbines, renewable energy, transmission, reserves, wind capacity, wind forecasting, wind integration.

1.0 Germany Profile

Germany is the global leader in the production of wind power, with an installed power capacity from wind turbines of more than 20,000 megawatts (MW) as of the end of 2006. This accounted for about 27% of the world's installed wind power capacity. More than 2,200 MW of new wind projects were installed in Germany in 2006 (Global Wind Energy Council 2007).

The German electricity supply is dominated by thermal-based fossil fuels (lignite and coal) and nuclear facilities (Table 1). Under the "Nuclear Exit Law," nuclear power is to be phased out and limited to only 9% of total generation capacity by 2020. Furthermore, the government has a policy to decrease the reliance on imported oil for energy needs and to meet national and international emission reduction targets (International Energy Agency 2002). These energy policy goals have the German government seeking alternative sources of energy, and Germany plans to increase its use in natural gas to 20% in addition to focusing on developing renewable sources of energy, mainly from wind power production.

Table 1. German electricity generation by fuel source, 2006

Hard Coal	21.4 %
Lignite	23.9 %
Oil	1.7 %
Natural Gas	11.6 %
Hydro	4.4 %
Nuclear	26.3 %
Wind	4.8 %
Other	6.0 %
Source: Cocortium Energy Balances (in German). http://www.ag-energiebilanzen.de/. (accessed March 2, 2007).	

Schleswig-Holstein, the northernmost state in Germany, has the highest density of installed wind generation capacity in Germany. Schleswig-Holstein is connected to the rest of Germany and the continental Union for the Coordination of Transmission of Electricity (UCTE network via a double-circuit 380 kV transmission line and a double-circuit 220 kV transmission line. Both lines stretch from Hamburg in the South to Denmark in the North, and hence to the Scandinavian electricity pool Nordpool. A single grid operator, E. On Hanse AG (previously Schleswag AG), is responsible for the distribution of electricity throughout the state. E. On Netz, one of four German Transmission System Operators, owns E. On Hanse.

2.0 The Organization of the German Transmission System

The German transmission system, made up of four separate transmission system operators (E. On Netz, En BW TNG, Vattenfall Europe Transmission, and RWE TSO) with 380 kV and 220 kV networks, is interconnected through international tie-lines to neighboring countries as part of the synchronously operated European extra-high-voltage (EHV) system. Several control areas form a control block, the coordinator of which maintains the exchange balance with neighboring blocks, and is responsible for the respective metering and accounting. The networks of the four German transmission system operators (TSOs) constitute the German control block of the UCTE, which also includes parts of Denmark, Luxembourg and Austria. The German block is part of "UCTE North," which includes the German block and the CENTREL network (Poland, Slovakia, Czech Republic, Hungary). While the TSOs provide any required regulation on their individual systems, differences between the scheduled energy exchange and real physical exchanges (inadvertent deviations) of control areas/blocks have to be collected and offset during the following week. The power-frequency monitoring system for UCTE North is located in Brauweiler, at the system control center of RWE TSO. It monitors electrical energy exchanges for all UCTE North, including the German block and the CENTREL network (VDN 2006).

UCTE relies on a number of technical rules and recommendations to ensure smooth operation of the system and to minimize grid disturbances. The rules and recommendations of the UCTE form a common basis for all of the TSOs, providing minimum requirements for the European transmission system as a whole. Furthermore, the UCTE rules and recommendations give the individual TSOs the option of going beyond mere compliance with these minimum requirements, implementing more stringent requirements or even defining these in greater detail. As a result, individual TSOs or regional TSO associations have drawn up national Grid Codes with a number of functions such as defining the sharing of responsibilities for security of supply, reliability and profitability for the system. For the TSOs to be able to meet their responsibilities, transmission system users must comply with the technical minimum requirements and rules specified in the relevant Grid Codes, which include those requirements established in the UCTE rules (UCTE 2004).

Since the electricity system in Germany is interconnected with other European countries in the UCTE, system operators in Germany are able to export and import excess power from neighboring systems. However, the TSOs are required to control the flow of electricity between Germany and its neighbors in compliance with UCTE standards allowing imports and exports as planned, scheduled power flows. The transmission system operator uses primary, secondary, and tertiary reserves to balance the system. The primary reserves can be available within thirty seconds of when it is needed. Secondary reserves can be activated and begin usage within five minutes and tertiary reserves are available within fifteen minutes of being called upon by the TSO (Gul and Stenzel 2005). TSOs typically procure tertiary reserves daily, while primary and secondary reserves are acquired every six months. In 2007, all TSOs are scheduled to have a common tendering process for reserves (Ernst 2006b).

The four TSOs balance each control area independently. Generation must be scheduled day-ahead, defined as 9.5 to 33.5 hours before real-time delivery in Germany. The day-ahead schedules cannot be adjusted unless there is a significant increase or decrease in either generation or load. Therefore, differences in advanced schedules and real-time deliveries must be balanced through reserve capacity, although the launch of an intra-day market in January 2006 is another potential option.

Germany requires the distribution and transmission operators to purchase renewable energy generation. The TSO or distribution system operator (DSO) that is closest to the plant where the renewable energy is generated must connect the wind generation to the grid (Bryans 2004). Since most of the wind that is connected to the network is below 100 kilovolts, many wind turbines connect directly to the distribution system. This requires TSOs and DSOs to have efficient communication so that the TSO can properly make adjustments to the electricity network based on the total amount of installed wind power capacity that is connected to the electricity network (Eriksen et al. 2005).

The distribution of installed wind power by each of the four transmission system operators (TSOs) is provided in Table 2, below. The largest proportion of installed wind capacity is located in E. On Netz, which connects over 7,700 MW of installed wind capacity, about 41% of the total installed wind power in Germany. The second greatest concentration of wind power is found in the Vattenfall Europe Transmission area, which has over 7,500 MW or 40% of the total installed capacity in Germany. The other two transmission system operators, En BW TNG and RWE TSO had about 300 MW and 3,500 MW, respectively.

Table 2. Installed wind capacity by transmission operator, 2006

Transmission System Operator	Installed Wind Power (MW)	Share of Installed Wind Capacity in Germany (%)	Share in Total Electricity Demand Within TSO (%)
E. On-Netz	7,794	41	32
RWE	3,494	18	37
Vattenfall Europe	7,571	40	18
EnBW	294	2	13
Total	19,153	100	100

Sources: Van Hulle, Fran. *Large Scale Integration of Wind Energy in the European Supply: Analysis, Issues and Recommendations*, "Country Profiles Wind Power and Grids in Selected EU Member States - Germany", European Wind Energy Association, p. 17. Personal Communication, Dr. Bernhard Ernst, RWE Transportnet 2 Strom GmbH, August 28, 2006.

The TSOs are responsible for covering balancing costs in proportion to their load share and not their share of wind energy. For example, as indicated in Table 2, E. On Netz has approximately 32% of total electricity load so they are allocated 32% of the costs of balancing wind power despite having 41% of the installed wind energy capacity. These shares change monthly, based on changes in each TSO's load share. Balancing costs, along with wind tariff costs, are then allocated to end-use customers in proportion to their share of total load.

An intra-day market was started in Germany in January 2006. Power traders nominate the buyer and seller on each side of the transaction and transmission path, and TSOs confirm the transaction. Nominations must be in four-hour blocks and scheduled at least one hour in advance. In 2007, the intra-day market will move to every 15 minutes, with 45 minutes advance notice required. About 80 power traders participate in the intra-day market, and transactions average about 1,300 megawatt-hours (MWh) per day, with a high of 2,000 MWh per day. Bids range from 5 to 100 MW, with a maximum limit allowed of 1,000 MW. Prices range from € 20-120 per MWh. By comparison, prices for reserves may range from € 50-200 Euros per MWh. The intra-day market could be used for balancing wind power, especially for covering wind forecast errors.

Wind generation that exceeds advance wind forecasts is typically sold in the market, most often the day-ahead market. For wind generation that is less than forecasted, TSOs typically rely on reserves, or if it is known far enough in advance, on the day-ahead market. The development of an intra-day market makes that market a possibility for handling both wind generation that is less than or more than forecasted (Ernst 2006b).

3.0 Energy Policies Promoting Renewable Resources

Germany has a long history of policies promoting renewable energy beginning in 1989, when a program providing a combination of fixed payments per kWh of electricity produced and incentives for private operators was created. The Electricity Feed-in Act was introduced in 1991, requiring grid operators to accept the renewable generation into the grid and pay 80% of electricity retail prices. A regional cap was applied to avoid unfairly disadvantaging one grid operator over another. Thus, the TSOs had to pay these feed-in prices until the share of electricity from renewable sources reached a cap of 5%. Nevertheless, the wind turbines installed under the Electricity Feed-in Act are concentrated in Northern Germany, leading the grid operators in the North to complain that they were at a competitive disadvantage paying higher prices for electricity as a result of the higher concentration of wind power (Ragwitz and Huber 2004).

Consequently, the Renewable Energy Act ("Erneuerbare Energien-Gesetz," EEG) replaced the Electricity Feed-in Act in 2000. Under the Renewable Energy Act, feed-in prices are no longer linked to electricity retail prices, but are set at a specific rate and fixed for 20 years. Grid operators must pay fixed tariffs for the feed-in of electricity from new small hydro up to 5 MW, incremental hydro upgrades up to 150 MW, landfill gas, waste treatment and mine gas, biomass, geothermal, wind, and solar powered facilities. Furthermore, the regional caps were eliminated and the total amount of feed-in reimbursements is distributed evenly among all TSOs and their electricity consumers. The wind energy and its related costs is passed from the distribution system operators to their TSOs and reallocated back to the distribution system operators in proportion of the TSOs' share of total electricity load.

The Renewable Energy Act was reviewed in 2002 and amended in August 2004. The feed-in tariffs for renewable resources are set at a fixed percentage ranging from 65 to 90% of the average end use price of the electricity generated from the renewable resource (Table 3). The feed-in tariff for onshore wind energy production on to the grid is set at 8.7 Euro cents/kWh for the first five years (International Energy Agency 2002). The feed-in tariffs will be reviewed every two years, the first occurring in 2007, with revisions to consider both technological and economic developments. The tariffs are also subject to an annual decrease of 1.5 or 2% depending on technology. Furthermore, the amended Act includes a detailed target for renewables to comprise at least 12.5% of electricity production by 2010 and at least 20% by 2020. The Act also calls for improved integration of renewable energy plants into the electricity system, complete with incentives for plant and grid operators to participate in the power management of facilities, and enforcement of the priority right for access and connection to the grid.

Table 3. Renewable energy feed-in tariffs

Resource/Technology	Capacity Restrictions	Tariff Rates by Size (Euro ct/kWh)	
Hydropower – new	up to 5 MW	up to 500 kW 50 kW - 5 MW	9.67 6.65
Hydropower – upgrades (tariff applies only to incremental difference)	5 MW - 150 MW	up to 500 kW 500 KW - 10 MW 10 - 20 MW 20 - 50 MW 50 - 150 MW	7.67 6.65 6.10 5.56 3.70
Landfill gas Sewage gas Mine gas (standard technologies)	Unrestricted	up to 500 kW kW to 5 MW mine gas from 5 MW	7.67 6.65 6.65
Landfill gas Sewage gas Mine gas (new technologies)	Unrestricted	up to 500 kW 500 kW - 5 MW mine gas from 5 MW	9.67 8.65 8.65
Biomass	up to 20 MW	up to 150 kW 150 - 500 kW 500 kW - 5 MW 5 MW - 20 MW	11.50 9.90 8.90 8.40
Biomass – waste wood	up to 20 MW	up to 150 kW 150 - 500 kW 500 kW - 20 MW	17.50 15.90 12.90
Biomass - CHP Technologies	up to 20 MW	up to 150 kW 150 - 500 kW 500 kW - 5 MW 5 MW - 20 MW	13.50 11.90 10.90 10.40
Geothermal energy	Unrestricted	up to 5 MW 5 - 10 MW 10 - 20 MW Greater than 20 MW	15.00 14.00 8.95 7.16
Wind (on land)	Unrestricted	All sizes	8.7*/5.5**
Wind (offshore)	Unrestricted	All sizes	9.10*/6.19**
Solar PV – building integrated	Unrestricted	up to 30 kW 30 - 100 kW greater than 100 kW	57.4 54.6 54.0
Solar PV - façade systems	Unrestricted	up to 30 kW 30 - 100 kW greater than 100 kW	62.4 59.6 59.0

* Rate available for the first five years for on shore projects and first 12 years for offshore projects. Onshore projects with higher yields and offshore projects in deeper waters may be eligible for an extension of the higher rate tariff.

** Rate provided for the remaining 20-year project life.

Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. *The Main Features of the Act on Granting Priority to Renewable Energy Sources (Renewable Energy Sources Act) of 21 July 2004*. Available http://www.bmu.de, accessed August 2006.

The tariff rates were adjusted to better reflect both cost and non-cost factors during installation. In the case of onshore wind energy, the support level was decreased significantly, especially for installations located on sites with very high yields. For installations at locations characterized by average yields, the tariff level was moderately decreased, presumably to provide incentives for more rapid technological progress, although opponents have criticized the Act for providing incentives to develop sites with poor wind resources. Offshore wind energy plants receive high-level feed-in tariffs for the initial 12 years after installation (compared to 5 years for wind onshore).

A driving force behind the German renewable energy policies is the need to meet emission reduction targets. Germany signed the Kyoto Protocol in 1997, which legally binds Germany to reduce carbon dioxide and five other greenhouse gas emissions. The European Union as a group agreed to reduce greenhouse gas emissions by 8% based on 1990 levels. Under the Kyoto Protocol and the burden sharing agreed among the fifteen participating EU Member States, Germany committed to reducing its greenhouse gas emissions by 21% between 2008-2012 compared to 1990 levels. Above and beyond the requirements under the Kyoto Protocol, Germany set a national target for the reduction of carbon dioxide emissions of 25% below 1990 levels (Federal Ministry for the Environment 2005).

Other sources of funding for the wind industry come from the German government, which has aided the development and promotion of renewable resources in Germany. Between 1975 and 2000, the government provided over $215 million (1995 dollars) of research and development funds for wind turbine technology. Germany began the 250-kW Prototype Program for wind turbines in 1986. The program subsidized the first five turbines of a company after the prototype was constructed and tested, successfully installing more than 50 commercial wind turbines at a time when market conditions were not conducive for wind development (Gilecki and Poling 2005). This effort was followed by a 100 MW program (later a 250 MW program) that subsidized wind projects by providing a payment of € 0.04/kWh (later reduced to € 0.03) for wind generated electricity. Participants could choose the subsidy or a 60% capital investment grant for the cost of the facility (Lauber and Lutz 2004). These German government programs, in combination with the Feed-in Law, helped the market for wind power to take off, launching over 15 years of accelerated growth.

4.0 Market for Wind Power Development

Wind resources are most prevalent in the northern states, specifically those bordering the North and Baltic Seas. Onshore developments are concentrated in the states of Lower Saxony, Schleswig-Holstein, North Rhine-Westphalia, Bradenburg-Berlin and Saxony-Anhalt (Van Hulle 2005). The greatest challenge facing the wind industry is not a question of economics or grid integration, although both are significant factors, but more of identifying suitable sites for new installations. Looking ahead, market participants expect to see relative declines in the number of new, onshore installations developed each year and greater contributions from repowering older facilities and new offshore installations. Despite uncertainties regarding the number of suitable onshore locations for wind development, Germany has added a significant amount of new onshore wind capacity over the past several years, although annual growth rates declined in 2003 and 2004.

With likely to be fewer opportunities onshore, participants in the German wind energy market are looking offshore for future projects. At the end of 2005 the Federal Maritime and Hydrographic Agency of Germany (BSH) designated three areas as suitable for offshore wind energy: “Nördlich Borkum" in the North Sea, “Kriegers Flak” and “Westlich Adlergrund” in the Baltic Sea. (Figures 1 and 2, BSH maps: North Sea and Baltic Sea). Twenty-nine applications in the national economic zone, which is 12 miles offshore, have been submitted to the BSH. Applications for eight wind farms within the 12 mile state territorial limit have been submitted to the states of Lower Saxony, Schleswig-Holstein and Mecklenburg-Western Pomerania. However, despite the large number of applications, unlike neighboring Denmark or the United Kingdom, Germany has not yet installed any facilities offshore. Enova has a 4.5 MW “near-shore” wind project in operation that is located within the Ems River near the entrance to the North Sea.

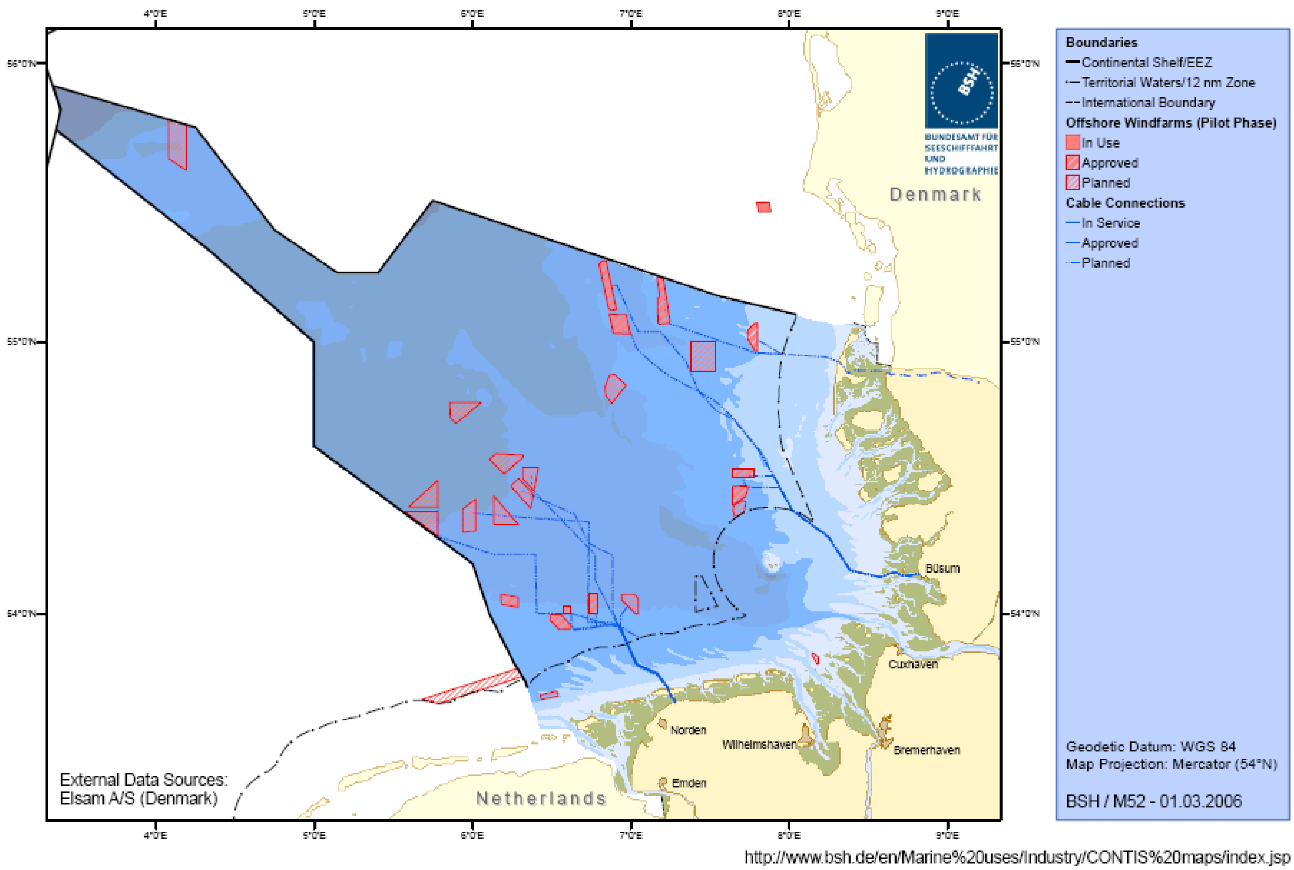
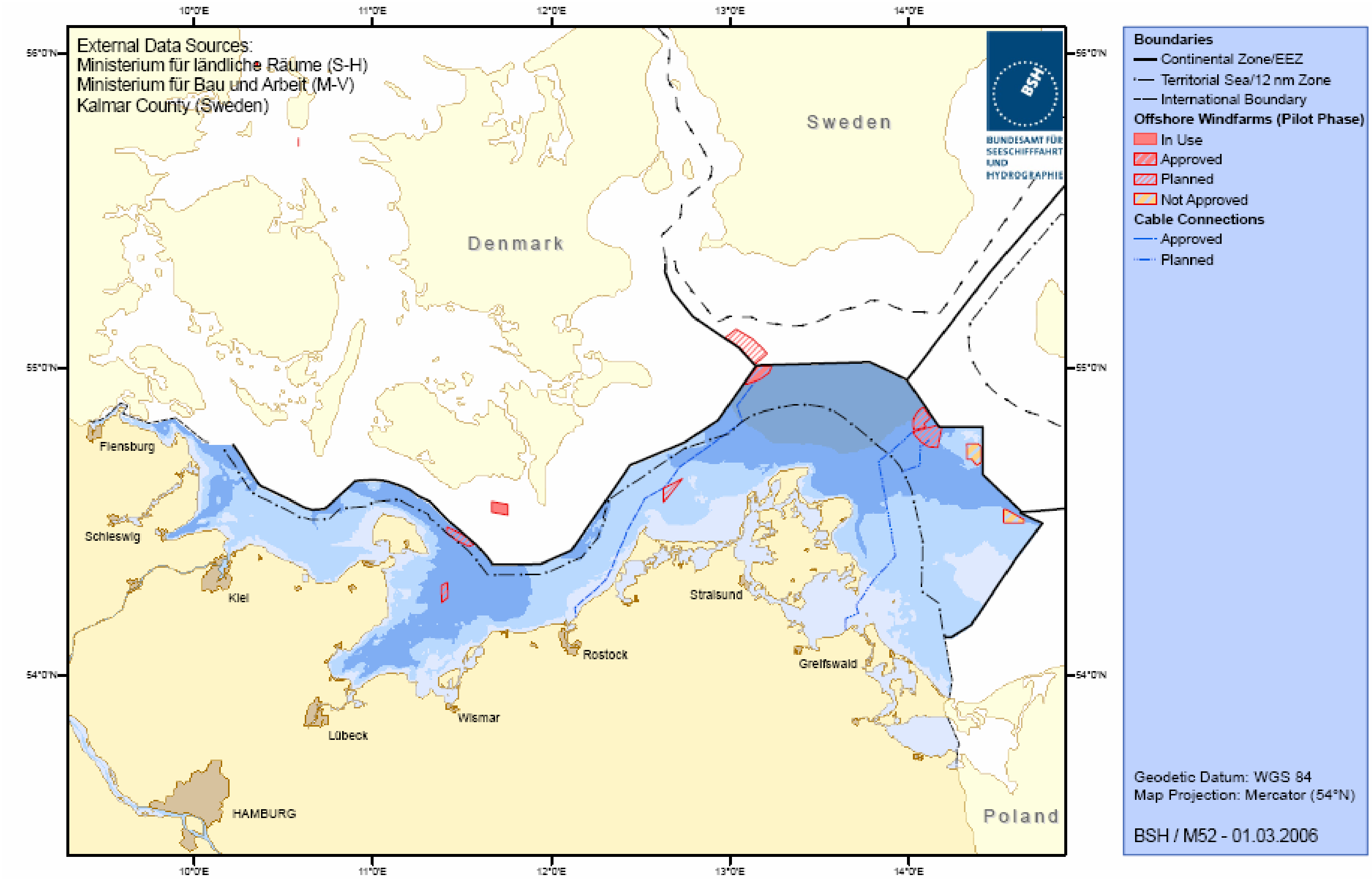


Figure 1. North Sea: Proposed offshore wind farms

Source: Deutsche Energie-Agentur (Dena). "Offshore-Wind.de." http://www.offshore-wind.de/show_article.cfm?cid=78. (accessed February 9, 2006).



http://www.bsh.de/en/Marine%20uses/Industry/CONTIS%20maps/index.jsp

Figure 2. Baltic Sea: Proposed offshore wind farms
Source: Deutsche Energie-Agentur (Dena). "Offshore-Wind.de." http://www.offshore-wind.de/show_article.cfm?cid=78. (accessed February 9, 2006).

More than 26,500 MW of offshore wind projects have been proposed, 24,000 in the North Sea and 2,500 in the Baltic Sea (Table 4). Many of the developers are waiting for the commercial viability of 4 and 5 MW wind turbines. Prokon Nord, along with Enercon and Repower installed several 4 and 5 MW turbines in 2004 and are awaiting completion of a two year study period prior to commercialization of the large turbines (dena undated). Furthermore, large offshore projects will require significant investments in transmission capacity and grid capabilities to bring the offshore power to on shore to load centers.

Two developments in 2006 may help stimulate offshore wind capacity in Germany. E.On Energy, Vattenfall Europe and EWE announced an offshore test wind that is scheduled to come on-line by 2008. The project is located about 30 miles off the island of Brokum and consists of twelve 5 MW wind turbines manufactured by RE Power and Multibrid. Subject to the approval of the European Commission, the German Environment Ministry pledged subsidies of 50 million Euros over five years (Repower 2006). Second, the German Federal Government enacted the Infrastructure Act, requiring transmission operators to pay for the costs of interconnecting offshore wind projects to the German grid for a limited time. To qualify, construction of offshore wind projects must begin before the end of 2011 (Kilpper 2006a).

Table 4. Proposed offshore wind projects in Germany

Project name	Developer	No. of Turbines (Phase I/ Total)	Total Capacity (MW)	Distance to the coast (km)	Project Status*
North Sea Projects					
Emden	Enova	1/1	4.5	<10m	OP
Wilhelmshaven	Winkra-Energie	1/1	4.5	<10m	AP
Sandbank 24	Fa. Projekt , Sandbank 24 & Co KG	80/980	4,720	100	AP
Borkum West	Prokon Nord Energiesysteme	12/208	1,040	43	AP
Dan Tysk	GEO mbH	80/300	1,500	45	AP
Borkum Riffgrund West	Energiekontor AG	80/458	1,800	40	AP
Borkum Riffgrund	Plambeck Neue Energien AG, Projektgesellschaft PNE2 Offshore AG	77/180	746	34	AP
Nordsee Ost	WINKRA Offshore Nordsee Planungs- und Betriebsgesellschaft mbH	80/250	1,250	30	AP
Offshore-Bürger-WindparkButendiek	OSB Offshore- Bürger-Windpark Butendiek & Co. KG Husum	80/80	240	35	AP
Offshore NorthSea Windpower	Enova Offshore, Projektentwicklungs & Co. KG	48/251	1,255	40	AP
Amrumbank West	Amrumbank West	80/80	400	35	AP
Nördlicher Grund	NEG Micon Deutschland (GEO, ABB, GREP)	80/402	1,206 -2,010	86	AP
Meerwind	Windland Energieerzeugungs	80/270	1,350	15/80	PR
Gode Wind	Plambeck Neue energien AG	80/224	1,120	45	AP
Global Tech I	Nordsee Windpower & Co. KG	80/320	1,440	75	AP
Hochsee Windpark, He dreiht	EOS Offshore AG	80/119	535.5	75	PR
Borkum Riffgat	Enova Energieanlagen	44	220	14.5	PR
BARD Offshore I	Bard Engineering	80/320	1,600	87	PR
Windpark "Austerngrund"	Global Wind Support	80/80	400	87	PR
HochseeWindpark Nordsee	EOS Offshore AG	80/508	2,286	75	AR
Windpark Nordergründe	Energiekontor AG	25/25	125	13	PR
Windpark "Deutsche Bucht"	Eolic Power	80/80	400	87	PR
Uthland	Geo mbH	80/80	400	49	PR

Table 4. Proposed offshore wind projects in Germany, continued

Baltic Sea Projects					
Project name	**Developer**	**No. of Turbines (Phase I/ Total)**	**Total Capacity (MW)**	**Distance to the coast (km)**	**Project Status***
Breitling	Wind-Projekt	1/1	2.3	-	OP
Rostock	Nordex AG	1/1	2.5	-	OP
Klützer Winkel	k.A.	1/1	-	5	AP
Kriegers Flak	Offshore Ostsee Wind AG	80/80	320.5	31	AP
Baltic I	Offshore Ostsee Wind AG	21	57.5	15	AP
Ventotec Ost 2	Arcadis Consult	80/200	600	104	PR
Sky 2000	Schleswig- Holsteinische Offshore Windpark Verwaltungs-gesellschaft mbH	-	175	13	PR
Arkona Becken Südost	AWE- Arkona- Windpark-Entwicklungs	80/201	1005	34	AP
Beltsee	Plambeck Neue Energien KG	25/59-83	415	9	PR

* Operating = OP, Permits Approved = AP, Application Pending/Proposed = PR

Source: Deutsche Energie-Agentur (Dena). "Offshore-Wind.de." http://www.offshore-wind.de/show_article.cfm?cid=78. (accessed February 28, 2007).

5.0 Integration of Wind Power on the Transmission System

The German Government established aggressive goals for the development of renewable energy resources, specifically onshore and offshore wind power. The development of wind power in Northern Germany and the North and Baltic Seas is expected to produce 2-3 GW of offshore wind power capacity by 2010 and 20-25 GW of wind capacity by 2025, most of which will be developed in the north, a region with relatively low electricity demand (dena 2005). This creates challenges for managing and balancing the flow of electricity. German TSOs make use of cross border connections to redirect power flows in scenarios where they have high wind power coupled with low power demand. For example, high, unscheduled flows of electricity from the north to the south, resulting from high wind production in Germany and Denmark were observed in the Netherlands and in Belgium in 2004. These unforeseen situations led to the curtailment of commercial contracts and cause concern regarding future additions of wind power capacity in Northern Germany (UCTE 2005b).

The German Energy Agency (dena) commissioned the study "Planning of the Grid Integration of Wind Energy in Germany Onshore and Offshore up to the year 2020," (the dena grid study). The study finds that the German transmission grid will require grid upgrades and extensions to allow for the further integration of renewable energy sources into the interconnected system. The regional concentration of wind power results in different load flows in the German interconnected system, including load flows through neighboring transmission systems. The change in load flows requires the re-dispatch of conventional power plants and reduced availability of reactive power (Hoppe-Kilpper 2006b). The study recommends upgrades to existing overhead lines, the construction of new extra high voltage lines, the implementation of quadrature-regulators (a transformer used to control the flow of real power on three-phase electricity transmission networks), and the implementation of units to provide reactive power. To support additional onshore wind development, dena anticipates that 390 km of existing power lines will require reinforcements, along with 850 km of new transmission lines by 2015 (approximately 5% of the current system). Between 2007 and 2010, the dena study predicts that 455 km of new lines will be required along with upgrades to 97 km of existing lines. The costs of these grid improvements are estimated to be €1.1 billion. Beyond 2015, dena anticipates that very significant grid extensions (approximately 1,000 km) will be required to adequately tie-in offshore wind resources to the interconnected grid (dena 2005).

Dena is working on a follow-up to its wind integration study that will examine the feasibility of incorporating 30% of generation in Germany from renewable energy. The study will consider how to optimize the expansion of the transmission grid and best use its reserves through improving wind forecasts; load management for some customers; the supply of regulating and reserve power from wind energy converters; and assessing the potential of different storage technologies. The "dena grid study II," as it is known, will be coordinated with a separate wind integration study being conducted by UCTE and the European Transmission System Operators (Hoppe-Kilpper 2006a).

There are three levels of grid operating parameters that govern the operations of the German transmission system. First there is the UCTE, the association of transmission system operators in continental Europe, which coordinates the operation and development of the electricity transmission grid in 23 European countries. UCTE issues technical standards in an operations handbook to coordinate the international operation of high voltage grids based on the use of synchronous generators. The "UCTE Operation Handbook" provides minimum technical standards and recommendations including operation policies for generation control, performance monitoring and reporting, reserves, security criteria and special operational measures. Then there is the Association of German Transmission Grid Operators (Verband der Netzbetreiber - VDN), which has established a network code establishing the minimum technical requirements and rules for access to and use of the transmission networks. Finally, the TSOs are ultimately responsible for assuring the technical security and reliability of the interconnected system, the technical quality of electric power supply, and non-discriminatory access to and use of their transmission systems. Thus, the TSOs have a grid code that incorporates both the guidelines of the UCTE Operation Handbook and the VDN network code but may go beyond these minimum standards as necessary to address reliability or power quality issues.

UCTE has issued a set of recommendations specific to the integration of wind power in Europe, but has not formally incorporated any guidelines within the "Operations Handbook." However, UCTE's general standards require that no more than 3,000 MW of generation can be lost due to grid events such as grid faults. If more than 3,000 MW of generation is lost then a system disturbance report has to be filed with the UCTE (UCTE 2005c). TSOs are concerned that a voltage drop in an area with a high density of variable-speed wind turbines could lead to a generation deficit greater than 3,000 MW. To prevent this, some TSOs are proposing more demanding connection requirements for wind generation. In order to meet these requirements, manufacturers of variable-speed wind turbines are implementing solutions to reduce the sensitivity of variable-speed wind turbines to grid voltage drops. While UCTE has not yet made these more stringent requirements a part of their "Operations Handbook," they have established the European Wind Integration Study to study the grid integration of wind power throughout Europe (UCTE 2006).

VDN has created guidelines, in addition to the network codes, for renewable-based generating plants' connection to and parallel operation on the high- and extra-high voltage network. The guidelines are intended to serve as a basis to the network operator and to the manufacturer and operator of these generating plants in the planning and decision-making process regarding the connection and operation of the plant. According to the supplemental guidelines, if the network voltage drops to less than 80%, the generating plant must be automatically disconnected from the network after 5 seconds. In a voltage drop above 85% a disconnection from the network is not admissible (VDN 2003).

E. On Netz and Vattenfall, the two TSOs with significant amounts of installed wind capacity, have upgraded their grid codes to include rules specific to the connections of wind plants that go above and beyond the minimum requirements established by UCTE and VDN. E. On Netz was among the first grid operator in the world to develop a grid code for wind and their statute for wind has formed the basis for grid codes in other countries, including the United States. Under their revised grid codes, E. On Netz requires wind generators to withstand a voltage drop to 15%. E. On Netz requires wind turbines to stay on-line (or ride-through) voltage drops to 15% for 625 milliseconds (E. On Netz 2003). In addition to the ride-through capability, E. On Netz requires wind facilities to provide grid support and reactive power for up to three seconds during a voltage drop (Luther et al. 2005).

According to their grid code, E. On Netz is legally able to limit or disconnect the power source from the grid network for several reasons, including acts of nature, potential risk to secure system operation, congestion or risk of overloading the system components, risk of islanding, hazard to steady state or dynamic network stability, critical increase of frequency, unacceptable network interactions, or for maintenance, repair and construction works. All connecters to the network must have approved switchgear and reactive power exchange, maintain operation during disturbances, meet a specified quality of supply level, and keep voltage and frequency levels within a specific range, and is responsible for the neutral point treatment of the system components (E. On Netz 2003). These provisions are consistent with the other German TSOs as well.

The E. On Netz grid code also provides blanket exemptions for wind facilities from certain requirements such as frequency stability (E. On Netz 2003). Vattenfall, however, allows exemptions from the standard grid code only under specifically negotiated agreements. Older facilities that do not have ride-through capabilities must still disconnect in the event of grid faults. Repowering old plants with new technologies may help to alleviate some of these concerns and should result in reductions in wind power disconnections from grid faults.

In June 2006, E. On Netz proposed revisions to its grid code for wind turbine. Among other things, E. On Netz is proposing requiring older wind turbines to undergo a retrofit to withstand voltage dips and avoid tripping off-line in the case of network faults. E. On Netz also plans to institute a monitoring program to ensure that wind projects are complying with fault ride-through requirements (Knight 2006b). For new wind installations from July 2006 onward, E. On Netz wants wind turbines to provide black start capability (Knight 2006a).

The dena grid study shows that the new grid codes and the technical improvements of wind turbines will improve system security by 2015 for the Northeast region and by 2010 for the Northwest region. However, due to the phasing out of nuclear facilities and the related shut-down of power-plants, the reliability and security of the Northeastern grid region will most likely worsen after 2015. Without countermeasures in place, the dena study concludes that serious grid failures and power station outages can be expected.

As noted above, TSOs rely on reserves to adjust imbalances in the electricity grid. Positive reserves are needed to balance for when wind power is unavailable or far less than projected, while negative reserves are required to balance for higher than expected electricity supplies. The dena study concludes that in 2003 an average of 1,200 MW (8% of installed wind capacity) and a maximum of 2,000 MW (14% of installed wind capacity) of wind-related positive regulation power had to be available on a day-ahead basis based on a total installed capacity of 14,500 MW. Similarly, an average of 750 MW (5% of installed wind power capacity) and a maximum of 1,900 MW (13% of installed wind power capacity) of negative regulation power had to be available on a day-ahead basis in 2003. The study further concludes that the positive reserve requirements will increase to an average of 9% and maximum of 19.4% by 2015 while negative reserve requirements will rise to an average of 8% and 15.3% (dena 2005). In contrast, E. On Netz assets that reserve capacities of 50-60% are required to correct for variations and imbalances of wind generation. They base their conclusion on the accuracy of wind forecasting and average deviations of –370 MW to 477 MW from projected wind power generation within their control area. In some extreme conditions, deviations from day-ahead wind forecasts were reported to be as high as +/- 2,900 MW in an individual hour (E. On Netz 2004).

E. On Netz has claimed that balancing reserves cost upwards of €11.8/MWh while the dena studies have estimated balancing costs at around €6-8/MWh, approximately 170-180% of market prices (Milborrow 2005a). E. On Netz quotes an annual cost of €100 million for balancing wind power, an amount significantly higher than comparisons made with utilities in the United Kingdom, Denmark, and the United States (Grotz 2006). There are several explanations as to why balancing costs in Germany might be higher than in other regions, the most significant of which is that each of the four TSOs operates more or less as an independent entity. Rigid day-ahead scheduling protocols and, until the beginning of 2006, the lack of an intra-day market probably also contributed to these balancing costs.

Wind has a limited capacity credit in Germany. A study conducted by E. On Netz concludes that wind farms contribute 8% of their installed capacity (E. On Netz 2004). Additionally, E. On Netz predicts that the relative guaranteed amount of capacity supplied by wind in 2020 will fall to 4%. These results are based on E. On Netz's projection of 48,000 megawatts of installed wind power capacity in 2020, which would replace 2,000 megawatts of traditional energy production sources (E. On Netz 2005). The dena study comes to a slightly different conclusion, finding that wind facilities will contribute 6% of nominal installed capacity, with 15% of electricity consumption supplied by wind energy by 2015. The dena study further concludes that additional reserve capacity is unnecessary (dena 2005).

Because of temporary overloading of selected overhead lines caused by wind power feed-in, E. On Netz established an obligatory active power management for wind turbines as part of their grid code. According to this practice, wind power supply must be reduced to a degree defined by E. On Netz to protect the system from overloads. The reduction of the power output must occur at a rate of 10% of total network connection capacity per minute from the time that the request is registered, without the system being disconnected from the network (E. On Netz 2003). For implementation, wind turbines and wind parks are equipped with communication technology and the corresponding control equipments. This "generation management" limits the wind power output to the grid at times when the local grid company is constrained. The responsibility for responding to generation management requests lies with the wind park operator who is called on to reduce output at E. On Netz's request. E. On Netz will lift the restriction once sufficient grid capacities are available (E. On Netz 2005).

In addition, wind plant operators must be able to comply with certain requirements such as reducing output, and riding through a low voltage, but are exempt from the basic requirements of providing primary control power and of island operating capability (E. On Netz 2003; Piwko et al. 2005). Each generator must be capable of operating with reduced power output and from any operating point to a maximum power value set by the TSO. If a reduction in power output is required, the generator must be able to reduce output by 10% of the network connection capacity per minute without disconnecting from the network (E. On Netz 2003).

6.0 Wind Forecasting and Prediction

The German electrical system has a forecasting system to assist in creating accurate forecasts for wind energy production. All TSOs use a wind forecasting system that was developed by the Institut fur Solare Energieversorgungstechnick (ISET) and is based on German Meteorological Center data. ISET uses a weather forecast as a basis for a forecast on wind speed and direction provided by the Deutsche Wetterdienst (DWD) along with other meteorological parameters for 30 different locations. The information from DWD is adapted to local conditions incorporating not only the location of the forecast but also the height of the wind turbines using a three-dimensional atmospheric model. Additionally, TSOs supplement the ISET wind forecast with their own wind forecasts. The RWE TSO is experimenting with combining different weather forecasting models into a single forecast to minimize wind forecast errors. Different weights will be applied to different wind forecasting approaches, depending on the weather pattern and how effective each wind forecasting method is considered to be with different weather patterns. Early results have proved promising, with the root square mean error being reduced in individual weather circumstances from 5% to 3.9% (Ernst 2006a).

7.0 Future Planning

Germany is moving ahead with a second phase study evaluating options for increasing power supply from renewable resources. Termed “dena Grid-Study II,” the new study, projected to start in May 2007, will examine grid operations assuming 30% of power generation is from renewable energy sources. The study will evaluate options for bulk electricity transmission from offshore wind to load centers. Furthermore, the dena Grid-Study II will be coordinated with a European grid study undertaken by ETSO and UCTE. This effort will identify mechanisms to optimize regulating and reserve power, including innovations in forecast quality, load management, and storage technologies (Ensslin 2006).

References

Bryans, Leslie. "International Experience: High Wind Plant Penetration and Grid Code Development". Presentation before the American Wind Energy Association's and the Utility Wind Interest Group's Wind Integration and Interconnection Workshop, Albuquerque, New Mexico. May 20, 2004.

Concortium Energy Balances. http://www.ag-energiebilanzen.de/. (accessed March 2, 2007).

Deutsche Energie-Agentur (Dena). Offshore Wind website, http://www.offshore-wind.de. 2006. (accessed February 9, 2006).

Deutsche Energie-Agentur (Dena). Planning of the Grid Integration of Wind Energy in Germany Onshore and Offshore up to the Year 2020: Summary of the Essential Results of the Study. 2005. www.dena.de. (accessed December 28, 2005).

E. On Netz. *Wind Report 2005*. 2005. http://www.eon-netz.com/Ressources/downloads/windreport2005_eng.pdf. (accessed December 28, 2005).

E. On Netz. *Wind Report 2004*. 2004. http://www.nowhinashwindfarm.co.uk/E.ON_Netz_Windreport_e_eng.pdf. (accessed December 28, 2005).

E. On Netz GmbH. *Grid Code: High and Extra High Voltage*. 2003. http://www.eon-netz.com/Ressources/downloads/enenarhseng1.pdf. (accessed November 22, 2005).

Ensslin, Cornel. "From dena study to dena Study II." Presentation before 1st Research Meeting of IEA Wind Task 25: Design and Operation of Power Systems with Large Amounts of Wind Power, Hanasaari, Finland. May 2006.

Eriksen, Peter Borre, T. Ackerman, H. Abildgaard, P. Smith, W. Winter, and J. Rodriguez Garcia. "System Operation with High Wind Penetration." *IEEE Power and Energy Magazine* (November/December 2005): 65-74.

Ernst, Bernhard. 2006a. "Optimal Combination of Different Numerical Weather Models for Improved Wind Power Predictions." Presentation before the Utility Wind Integration Group 2006 Fall Meetings, Oklahoma City, Oklahoma. October 25, 2006.

Ernst, Bernhard, RWE. 2006b. Personal Communication, July 17, 2006.

Ernst, Bernhard, RWE. 2006c. Personal Communication, August 28, 2006.

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. *General Information - Climate Protection*. August 2005. http://www.bmu.de/english/climate/general_information/doc/4311.php. (accessed December 12, 2005).

Gilecki, Mark, and Janice Poling. *Policies to Promote Non-Hydro Renewable Energy in the United States and Selected Countries*. Washington: United States Energy Information

Administration. 2005. http://www.eia.doe.gov/cneaf/solar.renewables/page/non_hydro/nonhydrorenewablespaper_final.pdf. (accessed September 15, 2005).

Global Wind Energy Council. "Global Wind Energy Markets Continue To Boom – 2006 Another Record Year." 2007. http://www.gwec.net/uploads/media/07-02_PR_Global_Statistics_2006.pdf. (accessed February 8, 2007).

Grotz, Claudia. "German Wind Market and Industry - Current Developments and Perspectives." April 28, 2006. http://www.german-renewable-energy.com/Renewables/Redaktion/PDF/en/en-Hannover-Messe-Energy-2006-Wind-Grotz,property=pdf,bereich=renewables,sprache=en,rwb=true.pdf. (accessed May 23, 2006).

Gul, Timur, and Till Stenzel. *Variability of Wind Power and Other Renewables: Management Options and Strategies*. Paris: International Energy Agency. 2005. http://www.uwig.org/IEA_Report_on_variability.pdf. (accessed November 2, 2005).

Hoppe-Kilpper, Martin. 2006a. "System Studies and Best Practices—Germany." Presentation before the European Wind Energy Association's Large-Scale Integration of Wind Energy, Brussels, Belgium. November 7, 2006. http://www.ewea.org/index.php?id=490.

Hoppe-Kilpper, Martin. 2006b. "Results of the Dena Grid Study." Presented January 24, 2006, in Brussels, Belgium. http://forum.europa.eu.int/irc/DownLoad/kfeuAFJ-mqG9um0Ju4TUUyLdGGkIsCj6VrQSZIWk30uHvh2H_3Gt2F0SiGkpj_qGsk7SFB/dena%20Grid%20Study_Br%FCssel.pdf#search=%22%22Results%20of%20the%20Dena%20Grid%20Study%22%22. (accessed August 22, 2006).

International Energy Agency. *Energy Policies of IEA Countries – Germany*. Paris: International Energy Agency, 2002. http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1097. (accessed November 11, 2005).

Knight, Sara. 2006a. "Network Operator Criticized: Law Firm Issues Grid Code Warning." *Windpower Monthly* (October 2006): 30-31.

Knight, Sara. 2006b. "E.On Netz Gets Innovative: Focus on Ways to Better Manage Wind." *Windpower Monthly* (June 2006): 32-33.

Lauber, Volkmar and Lutz Mez. 2004. "Three Decades of Renewable Electricity Policies in Germany." *Energy & Environment*, Vol. 15 No. 4. http://www.wind-works.org (accessed March 8, 2006).

Luther, Matthias, Uwe Radtke, and Wilhelm R. Winter. Wind Power in the German Power System: Current Status and Future Challenges of Maintaining Supply. *Wind Power in Power Systems*, ed. Thomas Ackerman, 232-255. England: John Wiley & Sons, Ltd. 2005.

Milborrow, David. 2005a. "German Report Skews Picture of Wind on the Grid." *WindStat* (Winter 2005): 1-3.

Piwko, Richard; Xinggang Bai, Kara Clark, Garry Jordan, Nicholas Miller and Joy Zimerlin. *The Effects of Integrating Wind Power on Transmission System Planning, Reliability and Operations: Report on Phase 2*. New York State Energy Research Development Authority, 2005. http://www.nyserda.org/publications/wind_integration_report.pdf. (accessed June 28, 2006).

Ragwitz, Mario and Claus Huber. *Feed-In Systems in Germany and Spain and a Comparison*. 2004. http://www.wind-works.org/FeedLaws/Germany/langfassung_einspeisesysteme_en.pdf. (accessed November 11, 2005).

Repower Systems AG. "REPower Supplies Six 5M for German Offshore Test Field." 2006. http://www.offshore-wind.de/media/article005995/021006_repower_eng.pdf. (accessed December 15, 2006).

Union for the Coordination of Transmission of Electricity (UCTE). "TSOs Set to Launch a Study on the Integration of Wind Power into Grid Operation (EWIS: European Wind Integration Study)". January 11, 2006. http://www.ucte.org/. (accessed February 7, 2006).

Union for the Coordination of Transmission of Electricity (UCTE). 2005b. *UCTE System Adequacy Retrospect 2004.* July 15, 2005. http://www.ucte.org/publications/library/e_default_2005.asp. (accessed January 10, 2006).

Union for the Coordination of Transmission of Electricity (UCTE). 2005c. *UCTE Operators Handbook, Policy 5: Emergency Operations, Final Draft*. September 11, 2005. http://www.ucte.org/pdf/ohb/Policy5_v0.9.pdf. (accessed November 22, 2005).

Union for the Coordination of Transmission of Electricity (UCTE). *UCTE Operation Handbook*. June 2004. http://www.ucte.org/pdf/ohb/Operation_Handbook_20.07.2004.pdf. (accessed January 27, 2006).

Van Hulle, Fran. *Large Scale Integration of Wind Energy in the European Power Supply*. Brussels, Belgium: European Wind Energy Association. 2005. http://www.ewea.org/fileadmin/ewea_documents/documents/publications/grid/051215_Grid_report.pdf. (accessed December 28, 2005).

VDN. "The Transmission System in Germany and in Europe." http://www.vdn-berlin.de/transmissionnetwork.asp. (accessed May 4, 2006).

VDN. *VDN Guidelines Renewable Energy Sources Connected to the High and Extra High Voltage Network*. August 2003. www.vdn-berlin.de. (accessed February 15, 2005).